

# Temperature Behavior of Field Deployed HDPE Geomembranes

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## ABSTRACT

An essential aspect of a composite liner system is to have intimate contact between the geomembrane and the underlying compacted clay or geosynthetic clay liner. Although in theory this coupling is excellent in vastly reducing flow through the composite system, in practice it is difficult to achieve. In the field, geomembranes expand when they are exposed to the sun and in so doing exhibit waves. These waves are particularly pronounced with HDPE geomembranes due to its characteristics of stiffness, coefficient of thermal expansion and modulus of elasticity. Although a general familiarity of this behavior is known, there has been very little research to quantitatively describe the phenomena. This paper discusses the actual monitoring of full scale geomembrane installations. Included is a three-part investigation on exposed as well as covered geomembranes. The paper provides data to better understand the temperature and wave behavior of deployed HDPE geomembranes and how they are affected by fluctuations in ambient conditions.

## INTRODUCTION

When considering the expansion and contraction of any material due to outdoor exposure it is important to understand the phenomena involved. Radiation, conduction and convection are the three mechanisms by which energy can be transferred within and between materials. Radiation occurs at the speed of light and can take place with or without the presence of matter between the radiator and the receptor. Radiation transfers energy by means of electromagnetic waves having an extremely wide range of wavelengths. As far as ambient conditions are concerned, the wavelengths of importance are those in which the sun, earth and atmosphere radiate. Solar radiation occurs at wavelengths in the range of 0.1 to 4.0  $\mu\text{m}$ . Conduction is the transference of heat through a body due to a temperature gradient. The heat energy diffuses through the body by the action of molecules possessing greater kinetic energy with respect to those possessing less. Finally, convection is the process of transfer of heat in a material by the movement of the molecular structure itself.

Radiation is generated by the intensity and duration of sunshine energy. In contrast to radiation, thermal gradients are induced by both conduction and convection. These latter phenomena result in a much slower transfer of energy and require the presence of some

intermediate substance such as air.

Temperature is the generalized measure of hot or cold in relation to the environment. As noted by Mather (1974), temperature is clearly the most commonly reported weather element. It can be defined in terms of the movement of matter. The more rapid the movement, the higher the temperature. In addition, it can be defined in relative terms on the basis of the heat of a given body. Heat moves from a body having a higher temperature to a body with a lower temperature.

There exists an important exchanged heat energy between the surface of the earth and the atmosphere. The temperature of the surface is directly responsible for the air temperature. The heat transfer from surface to air is partly due to the conduction of the layer immediately adjacent to the surface, although the effect decreases with distance from the surface. As the surface temperature itself depends on the intensity of the radiation, the air temperature also follows closely the variations of radiation. By examining the daily variation of air temperature on cloudy versus bright periods this relationship can be observed.

During the course of a day the air temperature rises rapidly in the first few hours of sunrise. Near mid-morning a considerable slowing of the rise occurs. This is due to the exchange of molecules of air taking place between the surface and higher atmospheric levels. The relatively cool descending air always has to be heated anew. The maximum intensity of radiation is usually reached at noon. The maximum air temperature lags behind two or three hours because heat is stored in the superficial layers of the ground from which it is slowly being released into the air. With setting sun, the air temperature falls slowly, to sink rapidly immediately after sunset. During the night the cooling process slackens but is continued until the daily minimum is reached shortly before sunrise.

This study investigates and reports as to the effect of temperature on geomembranes, in particular, HDPE geomembranes. The investigation consisted of three separate parts. Each part was a full scale study which made use of thermocouples extruded on or taped onto the geomembranes to measure temperature. The first part investigated monitoring different types of exposed geomembranes under direct sunlight. The second part involved measuring temperatures and wave behavior in exposed and covered geomembranes. The third part involved measuring temperatures of a geomembrane under various phases of landfill construction and waste filling. The latter is a long term investigation where thermocouples are monitoring the geomembrane from installation to the end of the landfill's post closure period. This latter investigation is ongoing, however, some initial data is presented.

## EQUIPMENT AND INSTRUMENTATION

Thermocouples are commonly used to measure temperature variations in materials and are particularly useful for remote sensing of temperature over long periods of time. Thermocouple technology is based on the principle that the electrical resistance of many substances varies with temperature. When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flows in the thermoelectric circuit. If the circuit is broken at the center, the net open circuit voltage is a function of the junction temperature and the composition of the two metals. All dissimilar metals exhibit this effect. For common temperature ranges, the voltage is linearly proportional to temperature. The only equipment that is required is a reference junction compensation unit to accommodate

environmental drift effects.

Thermocouples were chosen over other temperature measuring devices because they are robust, have a minimal inertia of adaptation, are not seriously influenced by radiation conditions, have an accuracy of approximately 0.2°C and are cost effective for remote temperature sensing, Landsberg (1967). ANSI Type J thermocouples were used for this investigation. They are made of 20 gauge thermocouple wire. The positive lead is iron and the negative lead is constantan. The leads are individually wrapped in Teflon® and then the entire wire is sheathed in Neflon®. This type of thermocouple wire is rated over a temperature range from -100 to +204°C. Over 1,000 meters of Duplex insulated TT-J-20-1000 thermocouple wire was used for this project.

Whenever possible, the thermocouples were attached directly to the geomembrane using HDPE extrudate from a hand held extrusion welder. This was the case for Parts I and II of the study, i.e., the exposed geomembrane studies. For the covered geomembrane study of Part III, the thermocouples were attached onto a sacrificial piece of geomembrane which was subsequently taped onto the in-service geomembrane. This precautionary step was taken so that a permit modification could be avoided and installation of the gauges could commence at the same time that the cell was being constructed.

### **PART I(a) EXPOSED GEOMEMBRANES - BLACK/WHITE STUDY SETUP**

The first part of the study was to determine the surface temperature of exposed HDPE geomembranes at a site near Philadelphia, Pennsylvania (Latitude +40°) over different seasons of the year. Both black and white HDPE geomembranes were evaluated, as well as smooth and textured materials. As seen in the photograph of Figure 1, the exposed geomembranes for this study consisted of four 5 m x 5 m sheets of geomembrane which were placed in a checkerboard pattern. They were placed on a compacted clayey silt subgrade which was relatively dry. The sheets of geomembrane were weighted down by 10 m sections of pipe to avoid wind uplift problems. As seen in the diagram of Figure 2, five thermocouples were installed on each of the four sheets giving a total of 20 thermocouples in the entire array. The data collected from each set of five thermocouples was averaged to give a representative response. All thermocouples were attached directly to the geomembranes with extrudate from a hand held extrusion welding gun, see Figure 3.

The geomembrane checkerboard was deployed in the field on four different occasions coinciding with the different seasons of the year. On all four of the test days, the weather was clear and sunny. The checkerboard of geomembranes was allowed to equilibrate for 24 hours before any temperature readings were taken. Temperature readings were obtained during the daylight hours on a subsequent sunny day after deployment.

### **PART I(b) EXPOSED GEOMEMBRANES - BLACK/WHITE STUDY RESULTS**

The results of this Part I investigation appear in Figures 4 (a) to (d). The temperature response curves are given for both black and white geomembranes as well as for smooth and textured materials. The response of the various geomembranes are given in contrast to the ambient temperature for the daylight hours of a continuous day.

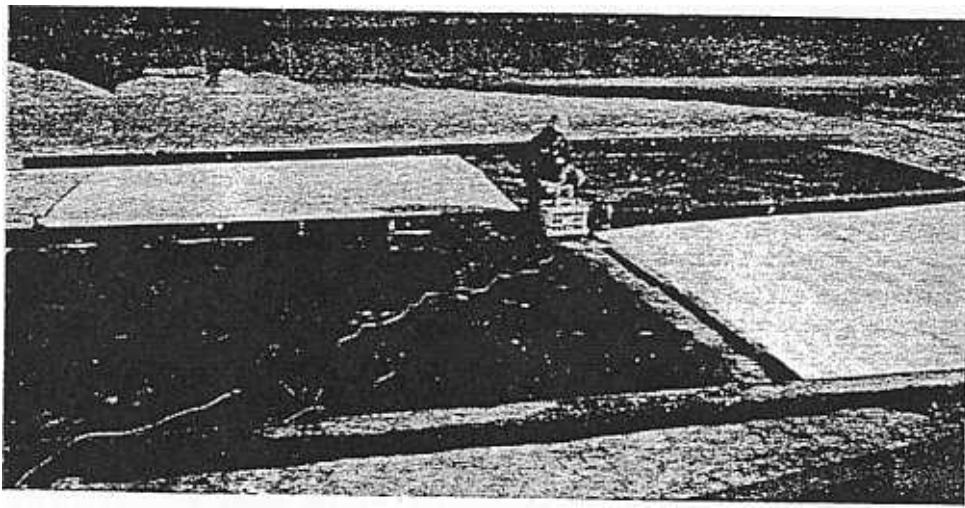


Figure 1. Photograph of the Exposed Geomembrane Checkerboard

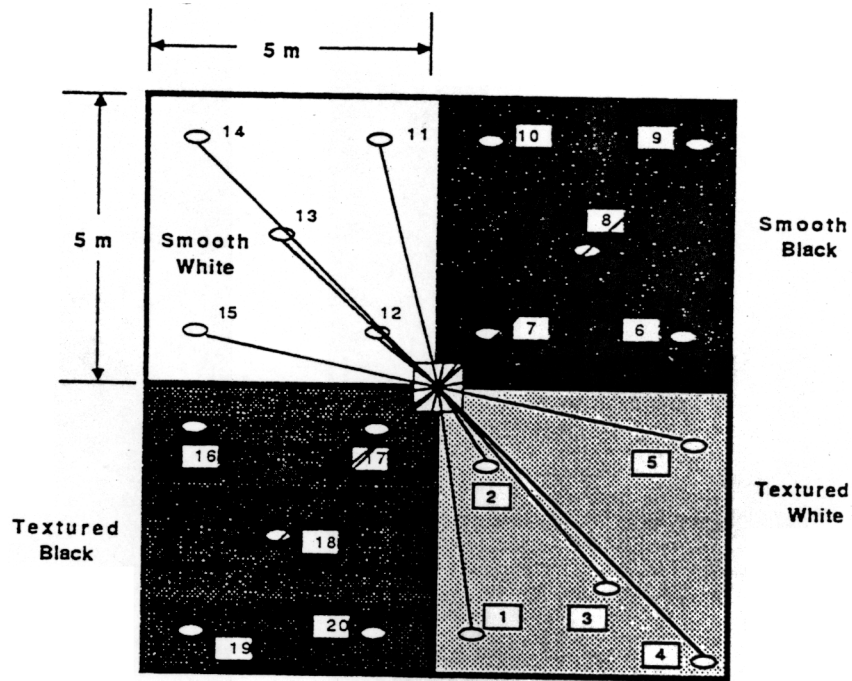


Figure 2. Schematic of the Geomembrane Checkerboard Showing the Location of the 20 Thermocouples

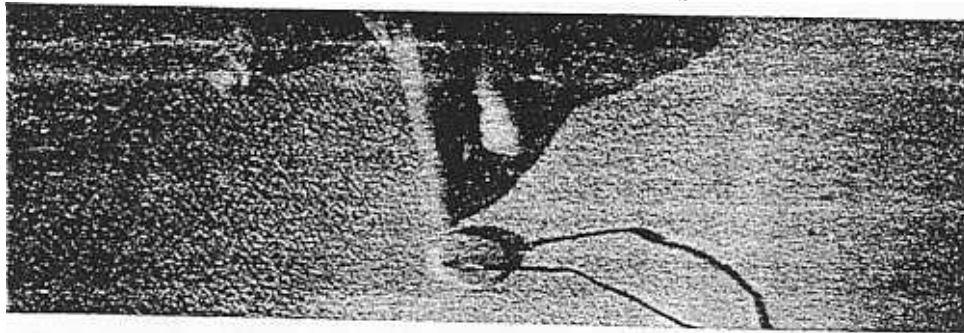
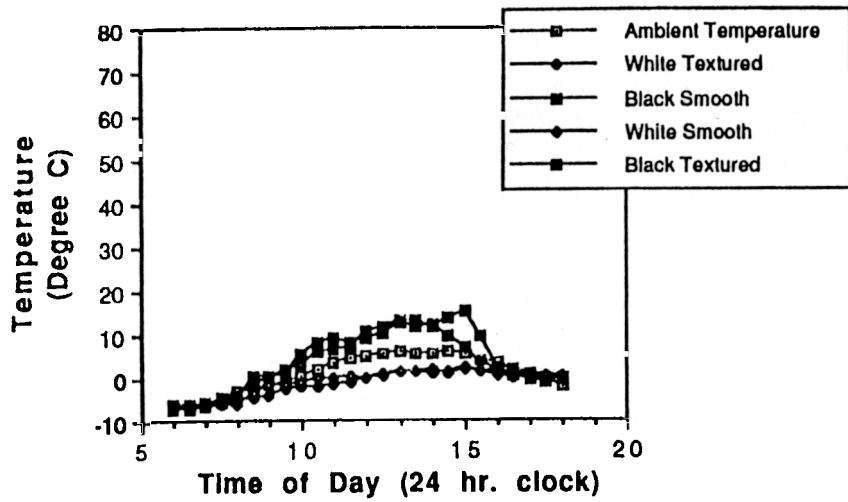
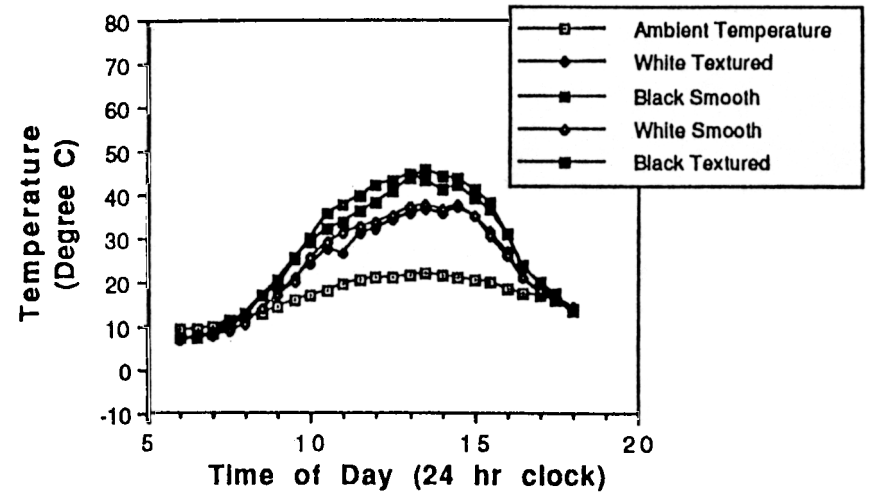


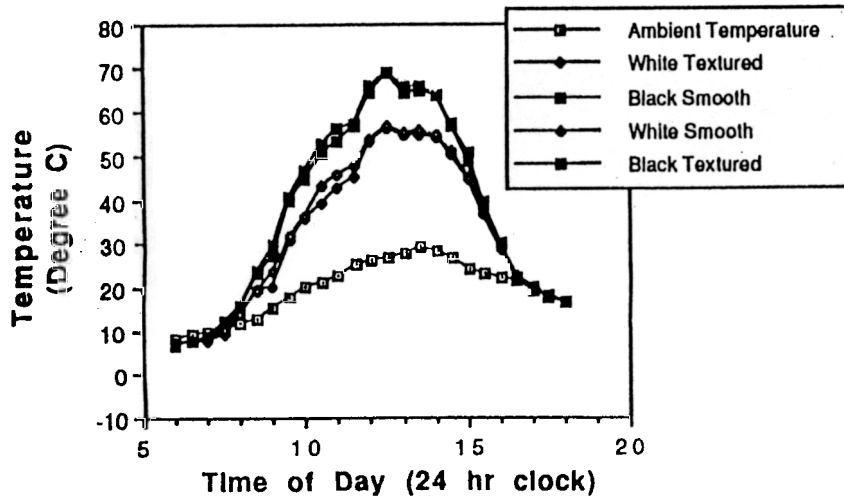
Figure 3. Close-up Photograph of a Thermocouple Extruded onto the Geomembrane



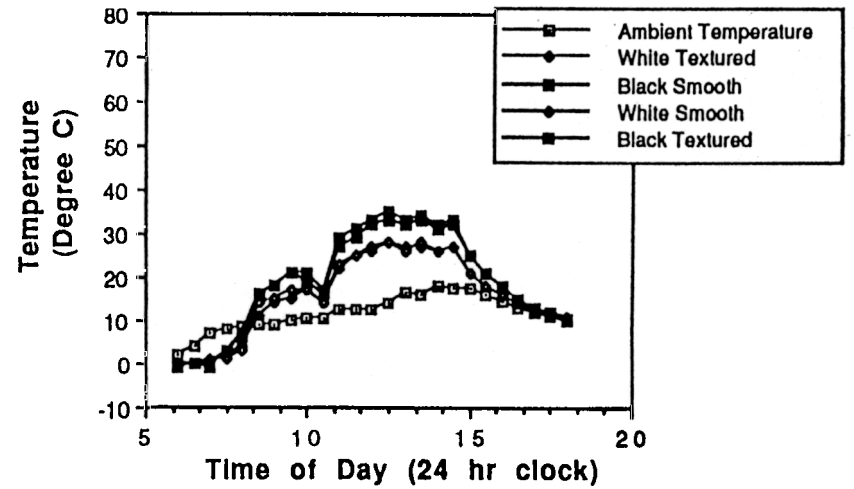
(a) Winter Results



(b) Spring Results



(c) Summer Results



(d) Fall Results

Figure 4. Results to Date of the Temperature Investigation for Exposed Geomembranes

